BUILD YOUR OWN

AUTONOMOUS ROBOT

SHAASTRA 2022
SESSION 2

What’s in store?

- What is Autonomy and Autonomous Navigation?
- Working of Autonomous Robots
- Simultaneous Localization And Mapping (SLAM)
- Implementation of SLAM in Coppeliasim

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Autonomous Robots

What is Autonomy?

- Autonomy is the ability to make your own decisions.
- In humans, autonomy includes things like walking, talking, waving, pushing buttons, etc.
- Autonomous Robots have the ability to make their decisions on their own and perform an action accordingly.
- True autonomous robots are intelligent machines that can perform tasks and operate in an environment independently, without human control or intervention.

- This level of autonomy gives the workforce the ability to delegate dull, dangerous, or dirty tasks to the robot so they can spend more time doing the interesting, engaging, and valuable parts of their job for which they are uniquely qualified.
- Industrial robot arms that work on assembly lines inside factories may also be considered autonomous robots, though their autonomy is restricted due to a highly structured environment and their inability to locomote.

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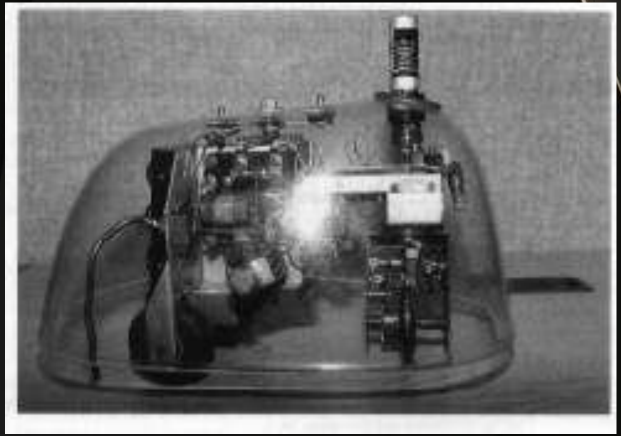
Some History...

- The first autonomous robots (Elmer and Elsie) were constructed by W. Grey Walter in 1948. They were called the tortoise robots!
- The robots were designed to show the interaction between both light-sensitive and touch-sensitive control mechanisms which were basically like two nerve cells with visual and tactile inputs.
- These systems interacted with the motor drive in such a way that the tortoises were actually finding their way around obstacles.They were allowed to randomly wander around the floor in no specific pattern they'd head towards whichever light they saw as a consistent part of the scanning process.



Examples of Autonomous Robots

- Starting with a bad example i.e not really a autonomous robot are the classic industrial machines. They are pre-programmed and cannot make decisions on their own.

- A good example of Autonomous Robot is the **Roomba**. It can act on its own, avoid obstacles, move around on the entire floor and clean it.


iRobot
Roomba
Vacuum Cleaning Robot
The power to change
the way you clean

Applications of Autonomous Robots

1. In Distribution centers and warehouses
2. Household work like cleaning and disinfection
3. As security robots
4. In hospitals and Healthcare
5. In Hotels and room service
6. In grocery stores
7. Delivery robots

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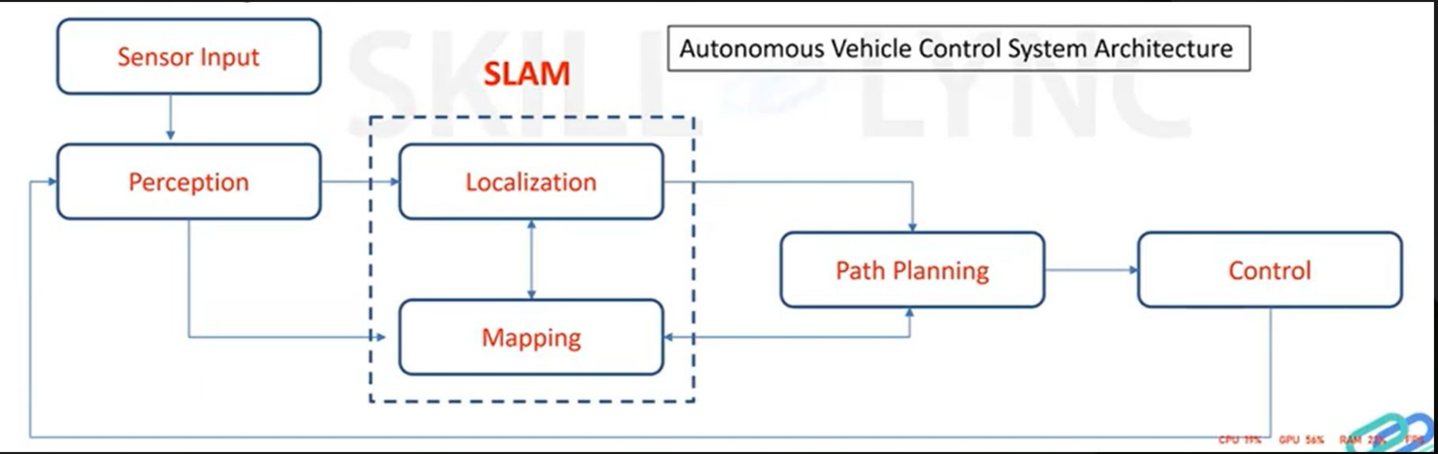
Autonomous Navigation

Autonomous Navigation is the ability for a vehicle to determine its location and plan a path to the destination without a human.

The different stages in Autonomous Navigation are:

- **Sense:** The robot collects information about the environment using various sensors. Laser scanners, stereo vision cameras (eyes), bump sensors (skin and hair), force-torque sensors (muscle strain), and even spectrometers (smell) are used as input devices for a robot to help it “see” and perceive its environment.
- **Perceive:** Interpreting the data received from the sensors and use it for various purposes like tracking objects, building models, estimate state and localisation.

- **Localisation and Mapping:** After tracking its location using the sensory data, it generates a map of its environment and estimate its exact position in that map
- **Planning:** After generating a map of its environment, it now creates a path to reach its goal.
- **Action:** Control the vehicle to follow the created path using various actuators like motors.



02
SLAM

Simultaneous Localisation And Mapping

- A method used for autonomous vehicles that lets you build a map and localize your vehicle in that map at the same time.
- SLAM algorithms allow the vehicle to map out unknown environments. Engineers use the map information to carry out tasks such as path planning and obstacle avoidance.
- SLAM is very widely used in robotic applications which require the robot to move in a new environment.
- Other Applications of SLAM are:
  - Smartphones
  - Augmented reality

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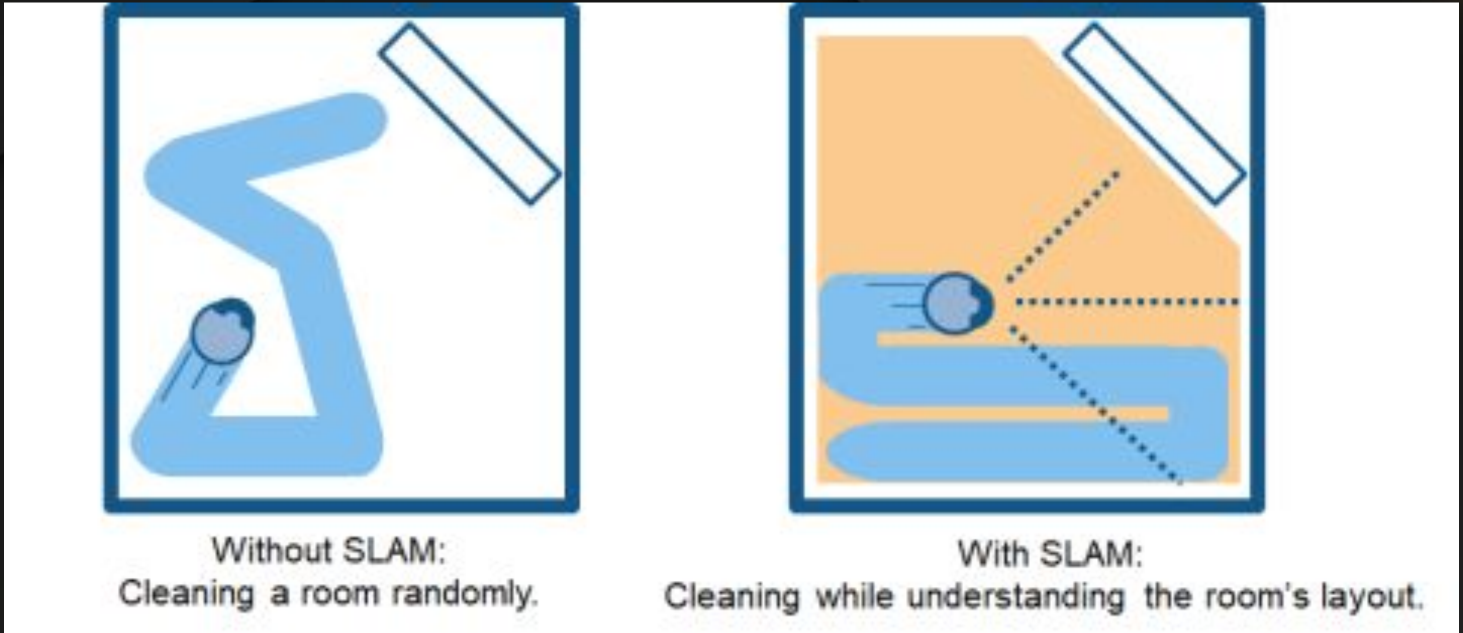
Localisation And Mapping

- Consider a situation where you don't have Google maps with you, So what you will do in that situation? You will probably look for street names or distinct landmarks nearby, and eventually, locate yourself. In robotics terms, this is called **localisation**. Once you know where you are and you know where you are going, you're all sorted.
- As we move, we know how far we moved by identifying landmarks we have previously observed. Furthermore, as soon as we see new landmarks and scenes, we can add those to our mental map to expand our territory of known places. Likewise an autonomous robot will keep on adding such landmark info they encountered and keep on increasing the terrain and get the map of the area it travelled. This is nothing but **mapping**.

Example of SLAM

Consider a home robot vacuum

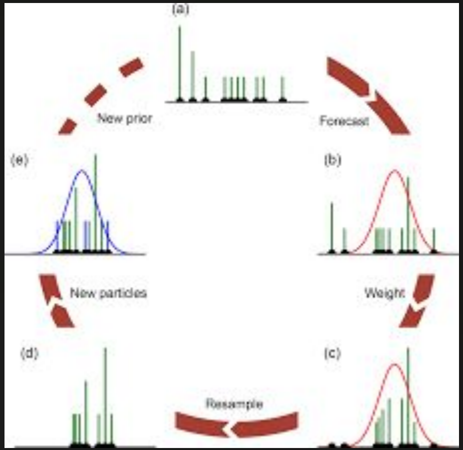
- Without SLAM:
  - Moves randomly and will not be able to cover entire home
  - Excessive power usage
  - Too much time
- With SLAM
  - Use infos such as no of wheel revolutions ,datas from sensor to determine the amount of movement
  - Process also called as Localisation
  - Using the sensors robot can create a map of obstacle in its surroundings and avoid the clean area twice
  - Process also called as mapping
- Both the mapping and localisation takes place simultaneously and thus the name

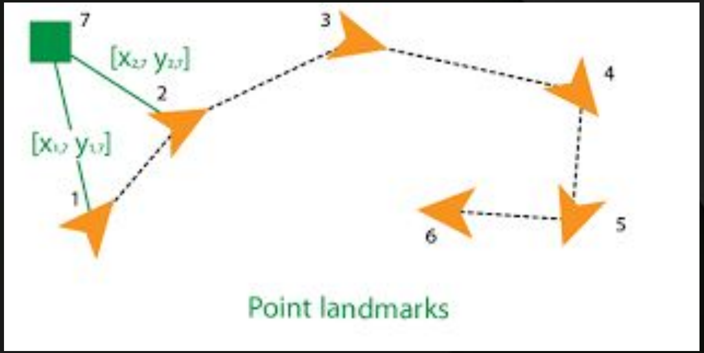

Without SLAM:
Cleaning a room randomly.
With SLAM:
Cleaning while understanding the room's layout.

SLAM Algorithms

There are many algorithms but they can be mainly classified into 2 sections:

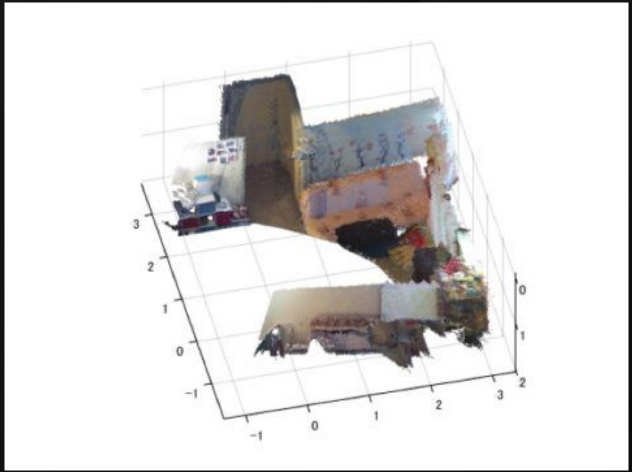
- **Filtering** - State is estimated "on the go" with latest measurements. Done using Extended Kalman Filter and Particle Filter
- **Smoothing** - Full trajectories are estimated using a complete set of measurements. Done using Pose Graph Estimation.





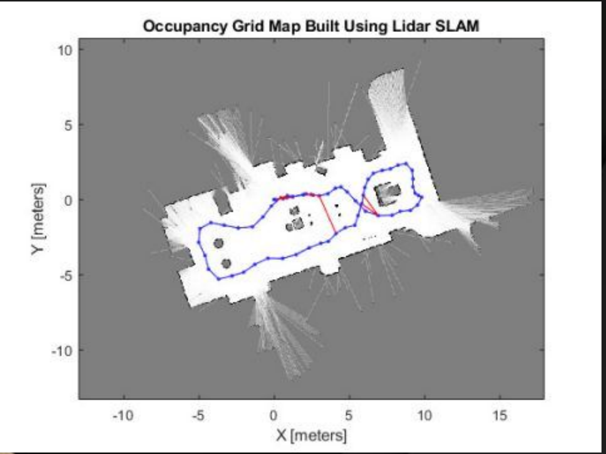
Visual SLAM

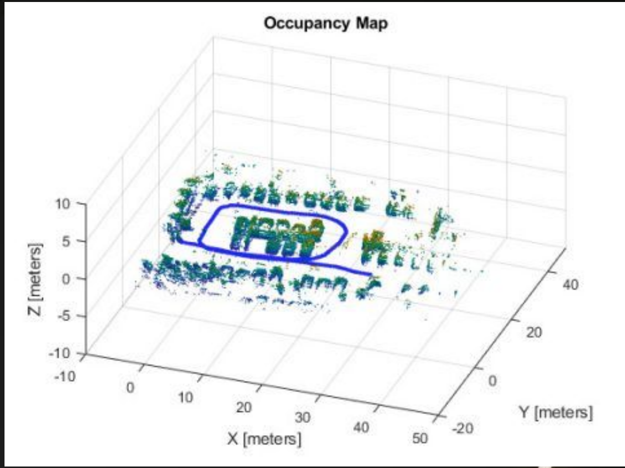
- Makes use of image acquired from cameras and image sensors
- Different types of camera can be used such as Monocular,Stereo,Depth cameras
- Algorithms can be classified into two categories
  - Sparse Method: Matches feature points of images
  - Dense Method: Overall Brightness of Images



LiDAR SLAM

- Abbreviates to Light detection and ranging,primarily uses a laser sensor
- Output values from laser sensors are generally 2D or 3D point cloud data
- Laser sensor point cloud provides high precision distance measurements and works effectively for map construction with SLAM





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Challenges in SLAM

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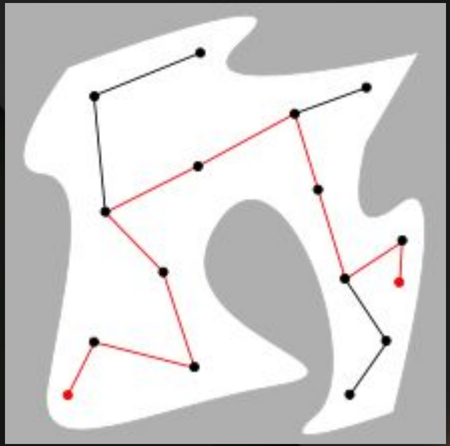
- **Localization errors accumulate, causing substantial deviation from actual values**
  - SLAM estimates sequential movement. The error accumulates over time, causing substantial deviation from actual values
  - Robot's starting and ending point no longer match up resulting in Loop Closure problem
  - Countermeasure is to remember some characteristics from a previously visited place as a landmark and minimize the localization error.
- **High computational cost for image processing, point cloud processing, and optimization**
  - To achieve accurate localization, it is essential to execute image processing and point cloud matching at high frequency.
  - Optimization calculations such as loop closure are high computation processes too.
  - Countermeasure is to run different processes in parallel. Using multicore CPUs for processing, single instruction multiple data (SIMD) calculation, and embedded GPUs can further improve speeds in some cases

Next Step: Path Planning

- Now that we have a map of the environment, the next step is Path Planning. Given the map, here the robot uses sophisticated algorithms to estimate the optimal path from the starting point to the destination.
- Popular Algorithms
    - Search based - A*
    - Sampling based - RRT and RRT*
- Path planning is just a subset of Motion planning. Motion planning also considers the velocity/acceleration the robot has to maintain throughout the path

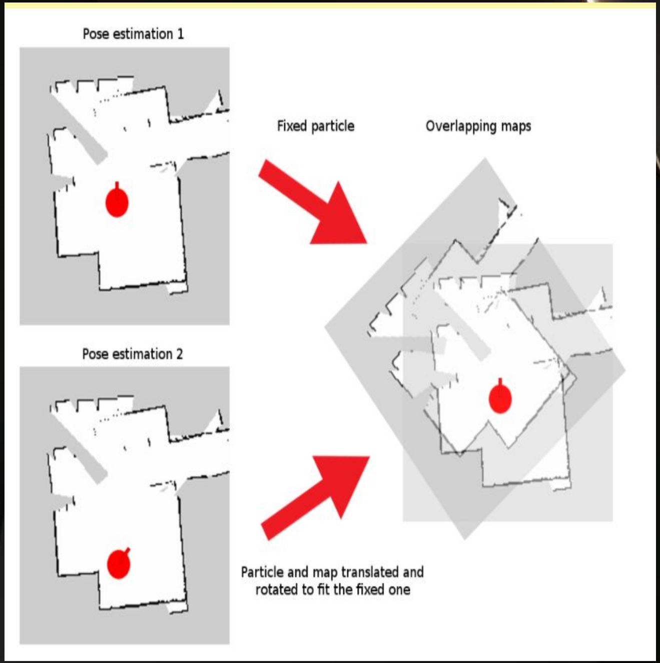


03

Let's SLAM the Robot!

OCCUPANCY GRID MAPS

- Now let's consider the movement of vehicle through a terrain we may consider the place as a collection of grids.
- Sensors will try to find object in place will try to get occupancy of each grid, but the sensors can't give 100% accurate value, so here we have to use the concept of probability.



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While using the sensors repeatedly we can increase the accuracy of our reading.

- Simply the probability of grid being occupied is → 0.5
- Probability of sensing an occupied cell → 0.7
- We want the probability of sensing an occupied sensor by using Bayer’s Theorem!

Probability of sensing an occupied cell → P(S/O)

Probability of being occupied is P(O)

Probability of being an occupied cell while sensing → P(O/S)

$$P(O/S)_1 = (P(O).P(S/O))/(P(O).P(S/O)+(1-P(O)).(1-P(S/O)))$$

$$= 0.5x0.7/(0.5x0.7+0.5x0.3)$$

$$= 0.7$$

$$P(O/S)_2 = (P(O/S)_1.P(S/O))/(P(O/S)_1.P(S/O)+(1-P(O/S)_1).(1-P(S/O)))$$

$$= 0.7x0.7/(0.7x0.7+0.3x0.3)$$

$$= 0.84$$

Here the probability of finding the cell being increased while repeating the process and there by we can get accurate value on each step.

THANK YOU

Aneesh Kandi
2nd Year Undergraduate
ee20b009@smail.iitm,ac.in

Sreehari M
2nd Year Undergraduate
me20b170@smail.iitm.ac.in

Q&A
Session